Mapping Operations In Alternate Orbits

- **Initial, high-level analysis was conducted to analyze mapping operation scenarios in aerobraking type of elliptical orbits *(Magellan mode)*.**

- **Topics covered in this presentation:**

  - ❑ **Review of general operational scheme for elliptical mapping.**
  - ❑ **Analysis of mapping characteristics of the sample orbits.**
  - ❑ **Analysis of orbit event timing (occultation and eclipse) in the sample orbits.**
  - ❑ **Discussion of the limitations of this preliminary analysis.**

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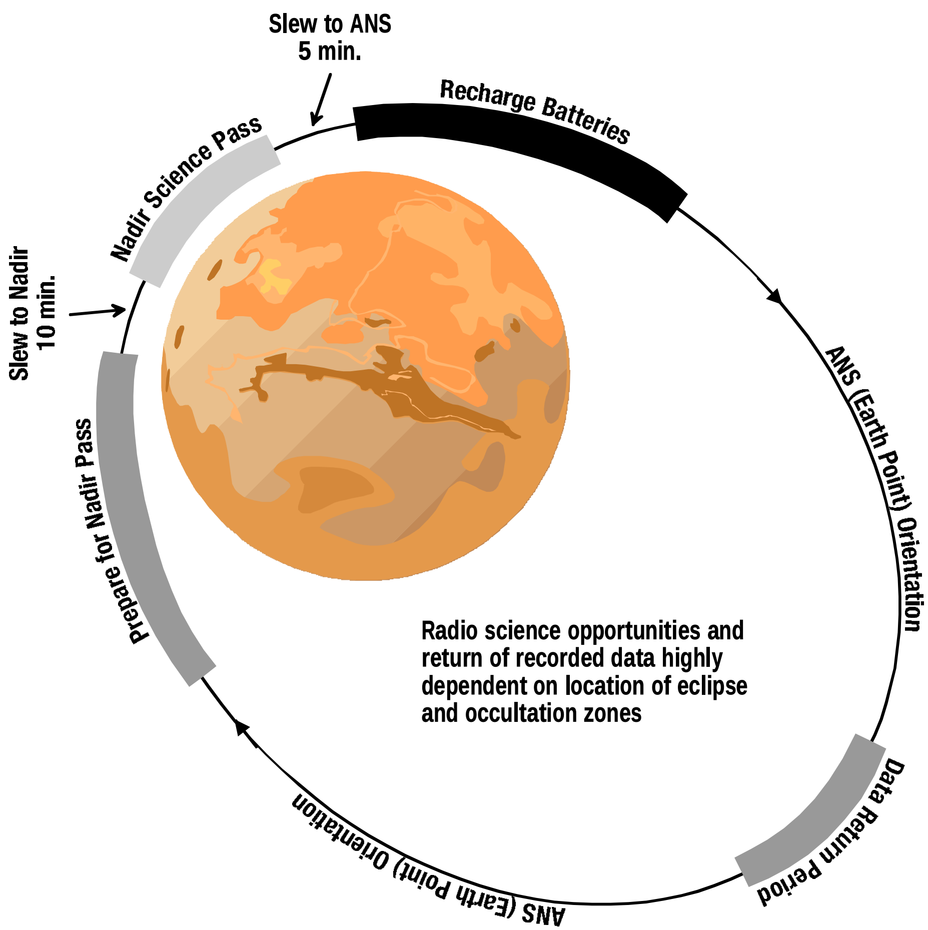
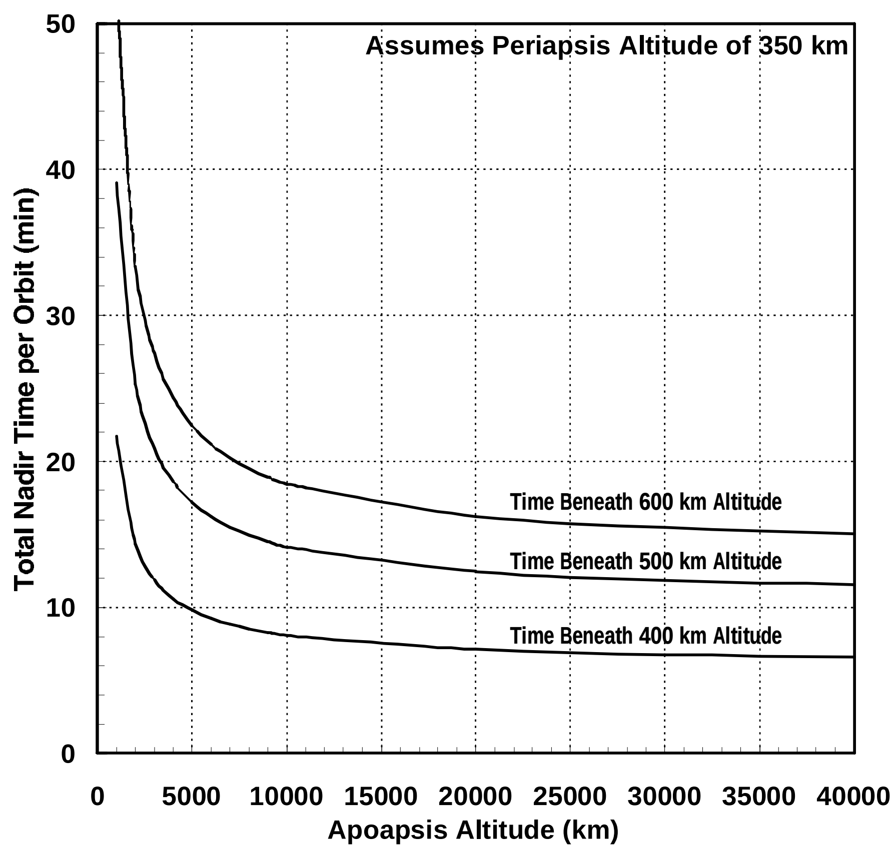
General Scheme For Elliptical Mapping





Analysis of Elliptical Mapping Orbit Geometry

- **The orbits used in this high-level analysis were chosen to be “representative” across different regimes and do not necessarily reflect the “optimal” choice of alternate orbit in the event that the normal mapping orbit cannot be reached.**
  - ❏ **A search of the entire solution space for “optimal” alternate orbits is extremely time consuming and has not been completed at this time. “Shopping list” of fall-back missions will be defined by early June (action item #23, Mission System). After launch, some will be worked in more detail.**
  - ❏ **Use of “representative” orbits is sufficient to characterize elliptical mapping operations.**

- ***Key Assumptions***
  - ❏ **ABX burn has been completed prior to start of elliptical mapping, periapsis altitude is 350 km.**
  - ❏ **Data collection occurs near periapsis only when altitude is less than 500 km.**
  - ❏ **Inclination of orbit is 92.866^{o} (MOI & normal mapping orbit target). No burns have been made to Sun-synchronize the elliptical orbit or freeze the periapsis.**

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Analysis of Elliptical Mapping Orbit Geometry

- **Scenarios chosen for this study are based on normal MGS mapping orbit and have similar ground track fill patterns.**

	Normal MGS	Scenario A	Scenario B
Nodal Period	117 minutes	About 3 hours	About 5.5 hours
Size (Hp x Ha)	353 x 408	350 x 2608 km	350 x 7680 km
Ideal Nodal Repeat Cycle	88 revs / 7 sols 58.6 km east walk	60 revs / 7 sols 85.9 km east walk	32 revs / 7 sols 161 km east walk
Ideal Nodal Super Cycle	6917 revs / 550 sols Q = 12.57636363	4717 revs / 550 sols Q = 8.57636363	2517 revs / 550 sols Q = 4.57636363
Swath Duration / Height	entire orbit	20 minutes (74^{o}) Periapsis ± 37^{o}	15 minutes (56^{o}) Periapsis ± 28^{o}
Periapsis Latitude Walk	none (frozen)	-17^{o} / repeat cycle	-6.1^{o} / repeat cycle
Mid-Latitude Visibility	not an issue	4.4 repeat cycles	9.2 repeat cycles
Node Walk	none (Sun synch)	-1.14 min / day	-1.75 min/day

Analysis of Elliptical Mapping Orbit Geometry

- **Nodal Period**
  - ❑ **Time in between two successive passages through the orbit's descending node**

- **Size**
  - ❑ **Mean altitude at periapsis and apoapsis**

- **Cycles**
  - ❑ **Repeat cycle refers to short term repeat. If there is an orbit walk of Z kilometers for a repeat cycle of X revs in Y sols, that means that the *equatorial crossing* (node) of orbit X + A will be Z kilometers away from the *node* of orbit number A.**
  - ❑ **Super cycle refers to the long term exact repeat of the *nodes* if the orbit is perfectly maintained (not possible due to navigational constraints). For a super cycle of K revs in L sols, the ground track spacing at the equator will be 360^{o}/K. The Q value denotes the number of orbits completed in one sol.**
  - ❑ **Because nadir data take periods occur only near periapsis and periapsis is constantly moving with respect to the node (equator), 360^{o}/K is not necessarily a good measure of the tightness of the final grid distribution. This calculation is only intended for comparison between orbits.**

Analysis of Elliptical Mapping Orbit Geometry

- **Swath Duration**
  - ❑ **Amount of time (centered on periapsis) that the spacecraft spends at 500 km in altitude or lower. The number in parenthesis next to the swath duration is how much of the ground, in terms of latitude, is covered in a single swath.**
  - ❑ **If the swath height is $\pm H^o$ and the latitude of periapsis is P^o, then spacecraft will be able to observe points on Mars in between the latitudes of $(P - H)^o$ and $(P + H)^o$ on each periapsis pass.**

- **Periapsis Walk**
  - ❑ **The negative number means that periapsis is moving (regressing) toward the ascending node in the clockwise direction (as viewed from the north trajectory pole). For example, suppose that the repeat cycle is X revs in Y sols, the periapsis walk rate is W^o per cycle, and periapsis is at the north pole on orbit number A. Then on orbit X + A, periapsis will be at a latitude of $(90^o - W)$, and orbit 2X + A periapsis will be at a latitude of $(90^o - 2W)$.**

- **Mid-Latitude Visibility**
  - ❑ **This metric measures how long a given latitude band will stay within the view of the nadir swath before the periapsis walk moves the swath away. The number is calculated by (2H)/W.**

Analysis of Elliptical Orbit Event Timing

- ***Key Operating Assumptions***

  - **When node time is beyond solar array gimbal limit, spacecraft must slew off Sun to point nadir.**
    - **No electricity is generated at this time.**
  - **Solar panels and both batteries are functioning normally, minimum battery SOC is 40%.**
  - **TWTA is powered on at all times other than during the nadir pass.**
  - **Instruments are powered on at all times.**
  - **Spacecraft remains in ANS (Earth point) at all times other than during the nadir pass. Therefore, spacecraft is subject to "cosine losses" on the solar panels due to the changing Sun-Mars-Earth geometry.**
  - **Because the spacecraft is in ANS at all times other than the nadir pass, radio science can take place (if sufficient power is available) if the Earth occultation zone is either 10+ minutes before or 5+ minutes after the nadir pass.**
    - **10 minute zone before - slew from ANS to nadir point**
    - **5 minute zone after - slew from nadir point to ANS**

Analysis of Elliptical Orbit Event Timing

- ***Power Analysis***

  - During elliptical mapping, there will be two possible zones of no Sun on the panels that can occur in either order and/or overlap:
    - "Sun eclipse zone" when the spacecraft passes behind Mars relative to the Sun.
    - "Data take zone" when the spacecraft slews to nadir near periapsis. If the data take time is D minutes, the amount of off Sun time is D + 15. The 15 minutes accounts for slew time to and from ANS.
  - Total amount of time in eclipse that spacecraft can tolerate depends on two prime factors:
    - Total power load, physical capacity of the batteries, minimum acceptable battery state of charge (currently 40%).
    - Absolute length of on-Sun time available to recharge the batteries (longer period orbits are better).
  - Maximum (estimated) combined off-Sun time per orbit as calculated by Wayne Sidney's power analysis tool:
    - 50 minutes for Orbit A (3 hour period)
    - 60 minutes for Orbit B (5.5 hour period)

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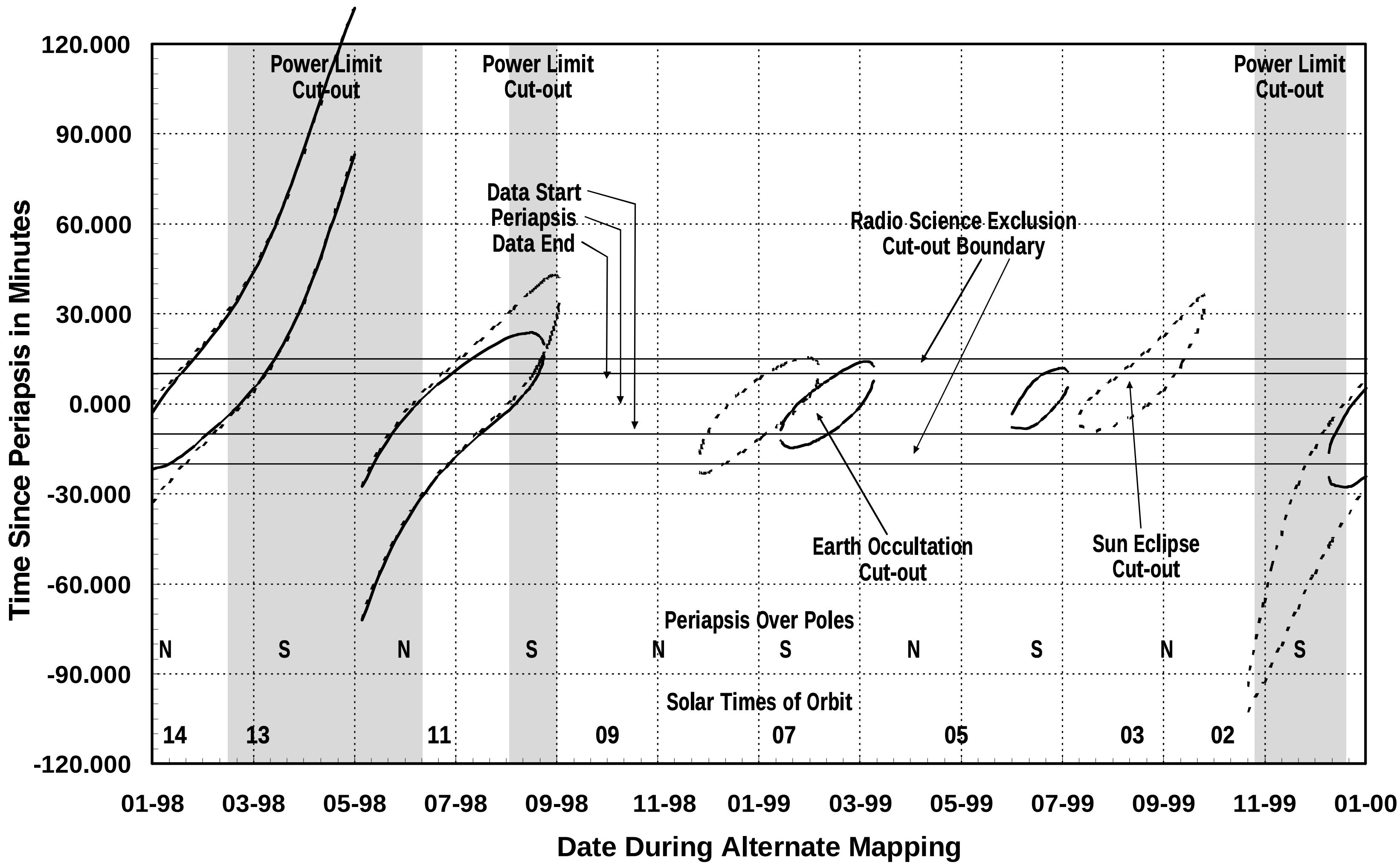
Orbit Event Timing
Scenario A



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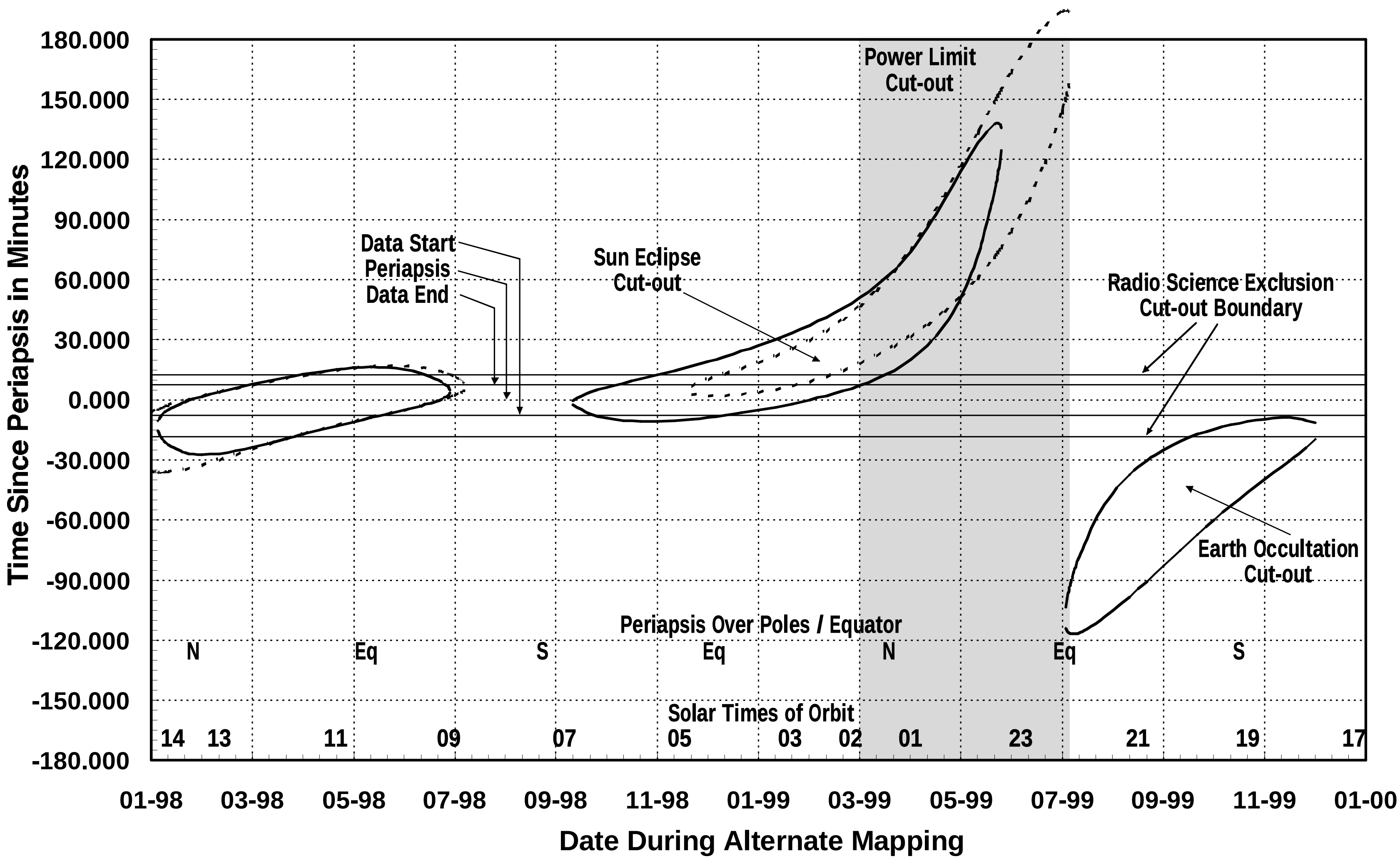
Orbit Event Timing
Scenario B



Limitations of This Analysis

- **Methods to improve power situation for questionable periods:**
  - ❑ **Cycle instruments on only near periapsis.**
  - ❑ **Cycle TWTA on only for radio science and data return.**
  - ❑ **Use Sun-Comm-Power attitude instead of ANS when recharging batteries.**
    - ❍ **This attitude points the spacecraft directly at the Sun and will eliminate the “cosine loss.”**
  - ❑ **Model the Sun angle on the solar arrays to a higher fidelity.**
    - ❍ **Current analysis assumed that solar arrays receive no Sun when spacecraft is nadir pointed. This assumption is not always true.**
  - ❑ **Shorten the duration of the periapsis data zone.**

- **This preliminary analysis assumed a specific scenario.**
  - ❑ **Conduct of mapping operations from an aerobraking orbit (non-Sun-synchronous, non-frozen).**
    - ❍ **Essentially, aerobraking is terminated with a periapsis raise, and mapping is conducted from that point.**
  - ❑ **Future work in response to Action Item #23 may produce an alternate orbit(s) optimized to provide better ground track coverage and eclipse geometry.**

Limitations of This Analysis

- **Realism of the scenario?**
  - ❑ **In order for the scenarios in this analysis to be viable for mapping, the spacecraft's power generation capabilities must be normal (no faults).**
    - ❍ **If power is good, chances are the spacecraft will still be capable of aerobraking.**
  - ❑ **Scenario A (3 hour orbit) may be realistic if completion of aerobraking will result in a node time earlier than 1:00 p.m. (gimbal limits).**
    - ❍ **Because of the long off-Sun times required for non-Sun-synchronous mapping, short orbits (2 hours) are not possible because there will not be enough time to recharge the batteries.**